

Gulf of Mexico Ocean Monitoring System

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Grant Number N00014-97-1-1020

<http://www.-mel.nrlmry.navy.mil>

LONG-TERM GOAL

The overall goal is to demonstrate improved efficiency in the process of oceanographic research through increased cooperation and collaboration both between our own participants within the Ocean Monitoring System (OMS) Program and also with other research efforts in the Gulf of Mexico whose interests were contiguous or overlapping. We began planning the program by identifying a large number of scientists, a total of nearly 20, who were well established practitioners of each of the disciplines necessary to address the program objectives. We enlisted their enthusiastic participation as Principal Investigators to work closely together to reach the program goals. Then, as the OMS Program evolved, each member of this group sought to establish relationships with productive individuals with common interests and external research programs with complementary objectives in order to save time and eliminate duplication of effort in our research.

As a vehicle for demonstrating this increase in efficiency, the scientific goal of the program is to prepare the most complete possible analysis and summary of the prevailing oceanographic conditions in the Gulf of Mexico and make it available to interested parties in near-realtime over the Internet. The results will be a resource for both military and civilian users to draw upon, and will increase public

Report Documentation Page				Form Approved OMB No. 0704-0188	
Public reporting burden for the collection of information is estimated to average 1 hour per response, including the time for reviewing instructions, searching existing data sources, gathering and maintaining the data needed, and completing and reviewing the collection of information. Send comments regarding this burden estimate or any other aspect of this collection of information, including suggestions for reducing this burden, to Washington Headquarters Services, Directorate for Information Operations and Reports, 1215 Jefferson Davis Highway, Suite 1204, Arlington VA 22202-4302. Respondents should be aware that notwithstanding any other provision of law, no person shall be subject to a penalty for failing to comply with a collection of information if it does not display a currently valid OMB control number.					
1. REPORT DATE 1998		2. REPORT TYPE		3. DATES COVERED 00-00-1998 to 00-00-1998	
4. TITLE AND SUBTITLE Gulf of Mexico Ocean Monitoring System				5a. CONTRACT NUMBER	
				5b. GRANT NUMBER	
				5c. PROGRAM ELEMENT NUMBER	
6. AUTHOR(S)				5d. PROJECT NUMBER	
				5e. TASK NUMBER	
				5f. WORK UNIT NUMBER	
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) Dynalysis of Princeton,219 Wall Street,Princeton,NJ,08540				8. PERFORMING ORGANIZATION REPORT NUMBER	
9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)				10. SPONSOR/MONITOR'S ACRONYM(S)	
				11. SPONSOR/MONITOR'S REPORT NUMBER(S)	
12. DISTRIBUTION/AVAILABILITY STATEMENT Approved for public release; distribution unlimited					
13. SUPPLEMENTARY NOTES See also ADM002252.					
14. ABSTRACT					
15. SUBJECT TERMS					
16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT Same as Report (SAR)	18. NUMBER OF PAGES 7	19a. NAME OF RESPONSIBLE PERSON
a. REPORT unclassified	b. ABSTRACT unclassified	c. THIS PAGE unclassified			

awareness of, and dependence on, accurate and comprehensive ocean conditions. The data will also be a resource for other research programs in the Gulf which require oceanographic data as inputs or as boundary conditions. Finally, the resulting combination of data acquisition, analysis and model implementation will represent a relocatable nowcast/forecast system, whose capabilities have been demonstrated in the Gulf, but which is equally applicable anywhere in the world.

OBJECTIVES

The scientific objective is to integrate a number of existing methods of data acquisition and analysis to provide initialization and input data to drive an operational nowcast/forecast numerical model capable of predicting currents and other ocean properties with 3 to 6 kilometer resolution throughout the Gulf. Existing techniques of data analysis are being refined to produce more accurate results and new data sources and new types of instrumentation are being explored to fill gaps in the available realtime database. An estimate of the accuracy of the various indirect measurements and of the numerical model results using realtime ground-truth data will be prepared and reported along with the results themselves wherever possible. Improved techniques of archiving, reviewing, retrieving and displaying the data are also being developed to enhance the availability of the data.

The Program objective has been for us all to work vigorously to broaden our circle of contact with other Gulf of Mexico Programs to explore opportunities to interact with other research groups for mutual benefit. These opportunities fall into three categories. The most obvious category involves interactions through which we learn of valuable data or innovative data acquisition techniques are available for our use. Another type of interaction results in the identification of someone who is interested in using our results in their work, which leads to the development of a consumer base. The most fulfilling interaction, however, is bilateral, where it is possible to collaborate with one or more groups to everyone's benefit. Examples of each form of interaction are described in Related Projects.

APPROACH

In the planning stage we identified the areas where important data was lacking or inaccurate and where our efforts were most likely to result in the greatest improvement in the specification of the prevailing conditions. A series of research tasks were developed to address the most critical issues.

During a previous Minerals Management Service sponsored study of Gulf of Mexico modeling, the Princeton-Dynalysis Ocean Model (PDOM) predictions on the continental shelf, performed by Richard Patchen, had been demonstrated by Peter Niiler to represent more than 60% of the variance in comparison with ARGOS tracked drifters deployed by Henry White. However, on the slope and in the deep Gulf the circulation is dominated by the Loop Current and associated warm and cold core eddies and the model hydrographic fields must be initialized with the Loop and eddy signatures in order to accurately represent the location and strength of these currents. The practical method of obtaining information on the location and strength of these structures in near-realtime is from satellite altimetry processed and corrected by Robert Leben and George Born. The density structure of the water column is, then, inferred from the surface height anomaly, using a techniques proposed by George Mellor and Lakshmi Kantha to estimate the structure with correlation functions based on regional hydrography. Since the accuracy of the surface height anomaly is critical, one major initiative is to refine determination of the surface height and of the geoid, which are both necessary to obtain the anomaly.

Another major research initiative was to gain improved understanding of circulation dynamics in the shelf edge and shelf slope regions. According to comparisons by Peter Niiler with his ARGOS drifters, Robert Leben's geostrophic velocities for depths greater than 200 m from the satellite altimeter account for more than half of the variance of the surface currents, so that Richard Patchen's PDOM, initialized with compatible hydrographic fields, would perform at least as well. We already know that PDOM, driven with realistic synoptic wind fields produces very good results on the shelf, but the dynamics of the shelf- break region are not well understood. From satellite AVHRR surface temperature images and current meter data (Nowlin, *et.al.*[1998]) it is evident that considerable shelf edge exchange takes place in the presence of both warm and cold core eddies. Furthermore, both the observational data (Hamilton, [1992]) and earlier PDOM results (Herring, *et.al.* [1998]) indicate persistent along slope currents in the range of 10 cm/sec and, for periods of a month or more sometimes 3 times as large, whose cause and even existence is not well documented. Therefore this region was selected for more study.

Even if the model physics and numerics were flawless, the accuracy of the model forecast would be limited by the accuracy of the input conditions. The availability of wind fields with adequate resolution in time and space has always been a severe model limitation. This is particularly true in the forecast mode, where small errors expand and propagate. In addition, earlier studies (Herring, *et.al.* [1998]) have shown the importance of including the influence of time varying river runoff from even smaller rivers. With rapid changes in along coast currents due to wind variation during frontal passages, the use of mean or climatological river flow could result in large errors in salinity distribution along the coast. Methods of improving the quantity and quality of these two types of ancillary data were selected to receive particular attention.

Finally, it has long been observed that the timing of the dominant Gulf event, the shedding of an eddy by the Loop current, remains a mystery. Although statistical boundaries can be placed on eddy shedding (Vukovich [1995]), the standard deviation is large, and the results are not particularly useful in practice. Furthermore, since the influence of the location of the Loop and the motion of the eddy which is shed have a profound influence on the circulation throughout the Gulf, some ability to anticipate or even to simulate the behavior of the Loop and eddy shedding in a deterministic sense would be extremely valuable. In the absence of information to the contrary, there is every reason to expect that the behavior of the Loop is at least correlated with the temporal and spatial variation of transport through the Yucatan Straight and a study of the relationship between them should be a starting point. In addition to the natural incentive to understand Loop dynamics for their own sake, there is the important further motivation that, in order to perform the nowcast/forecast, some near-realtime alias for the Yucatan transport distribution is essential. Remote sensing holds the most promise for timely data availability and, in the spirit of the satellite altimeter surveys performed in the Gulf proper, the choice of a Yucatan Straight alias is likely to be one of the ascending TOPEX tracks crossing the Caribbean Sea from Honduras to Cuba.

WORK COMPLETED

Many of the tasks related to the refinement of the surface height and the geoid for the satellite altimeter have been accomplished. On the R/V GYRE from April 19 through May 3, 1998, Frank Kelly and Norman Guinasso obtained detailed hydrographic sections along two TOPEX ground tracks and

one ERS ground track during the time of the satellite overflight. A total of 68 CTD casts and 44 XBT drops were made during the cruise. The data from these transects is available on the Internet. In a coordinated effort using a Naval P-3 aircraft, John Blaha performed an aerial survey of those and other additional satellite ground tracks, dropping AXBTs with an occasional AXCTD for reference and calibration. Due to instrumentation problems some of the data was not usable. The remainder has been forwarded to Wilton Sturges for analysis and calculation of the dynamic heights and height uncertainties. The dynamic heights in turn will be used to compare with the altimetry and to estimate cross-track velocities for comparison with the ARGOS drifters.

As an additional task under the OMS Program, Frank Kelly and Norman Guinasso also deployed three buoys that are part of the Texas Automated Buoy System (TABS) administered by Robert Martin, Jr.. Most of the TABS buoys are located on the inner shelf and measure surface currents and report the results in real time via cell phone. The OMS TABS buoys L, M, and N, are located along a TOPEX ground track further offshore in 55 to 105 meter water depths. Each of the OMS buoys reports real time surface current and buoy N at 105 m also is equipped with an ADCP that reports the real time current profile. Buoy N is actually located at a triple ground track crossover where an ERS ground track falls on a TOPEX ascending and descending crossing point, thus providing maximum opportunity for calibration and comparison. In addition to comparison with the geostrophic velocities along the satellite altimeter track and the dynamic heights from the hydrographic sections, surface velocities from all of the TABS buoys provide valuable comparisons with both the ARGOS drifters and with the nowcast/forecast calculations from the PDOM.

In addition to providing a selection of near-realtime Gulf of Mexico altimetry products on their web site, Robert Leben and George Born have continued to develop algorithms to reduce the orbit error and refine the geoid in order to improve the quality of their sea level fields. In a complimentary effort C. K. Shum and Michael Parke are developing a methodology for reducing the inconsistencies in the corrections applied to the various altimeter data sets, with the intension of preparing an improved altimetry product when they are all merged. In other OMS related activities, Robert Leben has made comparisons between the altimeter derived cross track velocities and those obtained from Peter Niiler's ARGOS drifters. He has also made comparisons of ALACE float measured temperature profiles with altimeter derived temperature profiles computed from Lakshmi Kantha's regression model relating sea surface height anomalies to the vertical temperature distribution.

Because of the value of altimeter data and since the coverage of the satellite altimetry is limited in space and time, other methods of obtaining additional altimetric information are being explored. The feasibility of using buoys containing differential GPS to measure the sea level is being studied under our OMS Program by Michael Parke and C. K. Shum. During the GYRE cruise differential GPS sea level measurements were taken during the satellite overflights and, using sea level from fiduciary sites in Galveston and Corpus Christi for calibration, are being compared with the satellite altimeter results and the dynamic heights from the coincident hydrographic section.

Although Gulf of Mexico tides are not significant in the deeper water, they are important in estuaries and coastal regions. Therefore, a complete description of the prevailing oceanographic conditions must include an analysis of the tidal constituents. Accordingly, ADCIRC, a finite element long-wave hydrodynamic model developed for the U. S. Army Corps of Engineers, (Westerink, *et.al.* [1993]) has been applied to the Gulf by Norman Scheffner using a 8895 node grid with a minimum

resolution of 1 to 2 km. Based on a year-long calculation, driven at the Florida and Yucatan Straights with eight Greenwich epochs, a harmonic decomposition has been performed to produce a data base of the 37 NOAA tidal constituents at each grid point.

Finally, Richard Patchen has successfully automated the operation of the PDOM and is producing real time nowcast/forecast circulation on the continental shelf. The system automatically seeks and retrieves National Weather Service 29 km ETA meteorological forecasts on the Internet. The system is being updated to obtain realtime river flow data over the Internet from the USGS offices in five states. Beginning with conditions from the last nowcast calculation, the model is driven with realtime data and the results are archived. The system will automatically refresh the OMS web site and transmit the results to the Master Environmental Library at NAVO for distribution and archiving.

RESULTS

Peter Niiler has completed the first phase of a comprehensive study that uses Lagrangian drifters to improve the understanding of circulation over the continental shelf rise in the northern Gulf of Mexico. This phase focuses on the extent to which remotely sensed dynamic height fields can be used in explaining the shelf slope current patterns. Using four deployments of 20 drifters each, in release patterns located in the vicinity of semi-permanent warm and cold eddies impinging upon the continental boundary determined from satellite altimetry supplied by Robert Leben. The comparison of current velocities from the drifters with geostrophic currents from altimeter data indicate that there is little correlation in water depths of less than 50 m, between 50 and 200 m the correlation improves but the drifters mostly follow isobaths rather than dynamic height contours, and in deeper water the drifters agree well with the geostrophic currents from altimeter data.

IMPACT/APPLICATIONS

From the beginning of the OMS Program all participants have been encouraged to make any and all OMS produced data and results on an OMS web site. The individual OMS web sites are linked to each other and to other web sites of collaborating programs. It is difficult to assess the present or future impact of the availability of these results. Certainly well known web sites such as Robert Leben's Near-Real-Time Gulf of Mexico Altimetry site are visited by a large number of people who presumably continue to return to the site because they need the data that he provides. The only way to know how useful the data are is to continue to develop relevant and convenient products and see whether a user-base develops for those products. If nothing else, the oceanographic research community will find it novel and refreshing to have observational data and computational results available in near-realtime rather than waiting years for a publication.

TRANSITIONS

We expect that the data available on our web sites are being used by other research groups. Obvious applications for the observational data are to augment an existing data set or to provide means of performing a skill assessment of a model simulation. A logical and obvious application of the OMS whole Gulf nowcast/forecast results is to be used to provide lateral boundary conditions to drive a smaller scale, local circulation model. In order to expedite the process of developing this type of user-base, we have been in contact with several groups that either have or plan to develop local models to

offer them nowcast/forecast boundary conditions. At the same time it is too early in the OMS Program to be describing how the results are being used, since many of the analyses are not complete.

RELATED PROJECTS

The scientific goal, to provide a complete summary of the prevailing conditions in the Gulf is beyond the resources of the OMS Program and perhaps any single effort. Therefore, at the outset we attempted to use the results of other programs to gain as much leverage as possible. As a result, we have allied ourselves with as many existing programs that we felt would benefit our effort, and also actively promoted, encouraged and fostered incipient studies. On an individual basis H. James Herring has made arrangements to provide outer boundary conditions from the PDOM nowcast/forecast for a modeling study performed under the direction of Dr. Robert H. Weisberg of the University of South Florida, also funded through the National Ocean Partnership Program (NOPP). In exchange we will receive data from the USF observational study on the West Florida Shelf which we will use for model skill assessment. We have also offered our nowcast/forecast for use as a boundary condition for an EPA regional modeling study of the Mississippi Sound. Another example of inter-program outreach is that Robert Leben is providing his Web viewer to the NOPP International Year of the Ocean (YOTO) drifter program to enable the participants to overlay their drifter tracks on Sea Surface Height maps. Similarly Frank Kelly and Norman Guinasso have welcomed guest scientists and students on their OMS cruises to participate in the observations or to perform their own independent experiment. An example of the former was the participation of Dr. Alberto M. Vasquez de la Cerda of the Instituto de Ingenieria, Universidad Veracruzana and several of his graduate students in the April cruise.

The most dramatic collaboration, however, has developed through the mutual recognition that a group of scientists at Centro de Investigacion y de Educacion Superior de Ensenada (CICESE) and a consortium of oil companies working in the Gulf were all as interested in the Yucatan Straights transport distribution problem as were the OMS Program participants. Based on lengthy discussions following a meeting in May, we agreed to collaborate on a major study to measure the distribution of transport through the Yucatan Strait and calibrate a satellite ground track to the eastern part of the Caribbean Sea with a hydrographic survey to monitor the transport there with altimetry. The results will contribute to improved understanding of the behavior of the Yucatan transport. They will also facilitate the use of the altimeter measurements as nowcast/forecast boundary conditions for the PDOM model. This coordinated research effort will permit the acquisition of a comprehensive and valuable data set that none of the parties to the agreement could have obtained individually. It also represents a giant step in international scientific relations and a furthering of the relations between industry, academia and government that was initiated under NOPP.

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